SCIENTIFIC BASIS OF HIGH-SCHOOL METHODS[1]

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The fundamental thesis of this paper is that, subject to certain modifications, the methods used by the outside world in acquiring knowledge or in solving problems are the best prototypes for the methods of the school.

All modern scientific endeavor whether in the natural or the human sciences is governed by two axiomatic principles, namely, (1) Make sure of your facts; (2) Convince yourself of the correctness of their interpretation. In both these respects the school needs to learn of the world.

Facts are acquired in two ways, either at second-hand through authority, or at first-hand through direct observation or observation aided by experiment. Bacon complained of his age that it was indifferent about making sure of its facts, being prone to accept them upon authority. The result was that the progress of knowledge was arrested, for nobody cared to verify alleged facts or to find out new ones. This resulted in endless processes of perfectly correct reasonings upon premises which had never been verified and hence might be false. Evidently such a state of mind could not lead to progress in real knowledge, for even the so-called final causes upon which the Middle Ages prided themselves were, as Bacon said, like vestal virgins, worthy of reverence, but unfruitful. Needless, perhaps, to say, Bacon's complaint was heeded, first in natural science and later in all science, until at present it has become almost instinctive for men to make sure of their facts before venturing to deduce conclusions from them.

At this point we need to make one of the modifications mentioned. In the outside world men always have to make sure of

[1] Read before Section L of the American Association for the Advancement of Science at the Chicago meeting, December 29–31, 1907.

the facts when they are at the frontier of race knowledge, for nobody knows what the facts are, hence nobody is able to transmit them by authority. But in the school it is different. The student is at the frontiers of his own knowledge, not at those of race knowledge, hence though he does not know the facts somebody does, namely the teacher or the author of his textbook, and is consequently able to impart them correctly by authority. Here is the cause for many a shipwreck in secondary teaching. It is so infinitely easier for teacher or text to *tell* the student the facts than it is to make him search them out for himself or verify them, that authority is made almost the only source of acquisition. If teaching is to be revivified by adopting the spirit of scientific investigation, Bacon's prescription respecting the acceptance of authority for truth must be accepted, but for a different reason. The teacher may say, "There is no question as to the correctness of these facts or these principles which I propose to impart by authority, for they have been sufficiently verified by scientific investigation. Do you presume to question the correctness of the law of gravitation, or the laws of motion, or that the earth revolves about the sun, rather than the sun about the earth as they thought in Bacon's time? Why can I not impart them by authority since their truth can not be questioned? Bacon's objection appears not to hold for the school." But, it must be urged in response, Bacon's reason for objecting to authority as the criterion of truth was its effect upon science; ours is its effect upon the student. His was objective and related to the progress of science; our is psychological and personal and related to the progress of the student. The effect of such a procedure is as bad upon the mind as it is upon science, for it results either in a spirit of dogmatism or of mental servility or both, while it hinders apprehension, overburdens memory, and tends to make knowledge inert or unproductive, to replace vividness and vigor by placidity and indifference.

A second important difference between the investigator and the student is that the latter must devote most of his energies to acquiring an epitome of race knowledge which the former has already mastered. For this reason the student cannot recapitu-

late even in outline all the processes that were involved in the first mastery. One youth cannot hope to pull on even terms against the efforts of thousands of men. How then can instruction cover the requisite ground and at the same time insure a scientific attitude of mind? The answer to this question is that both quantity of subject-matter and quality of thought-processes can be attained only by selecting for scientific treatment the important nuclei, or thought-nodes, in every subject. Here come in the categories of a scientific method, such as first-hand acquisition of facts by observation, or observation and experiment, the use of hypothesis and analogy in forecasting the probable explanation of the facts, the application of scientific rules of evidence for the determination of causes and effects, and the final verification of generalizations by the test of application to new cases. A study thus treated is attacked at its strategic points, and the whole thus quickly mastered in detail. All its subordinate parts find their natural places and may be rapidly acquired by less rigorous methods. The giving of facts and even of subordinate principles by authority may be in place, for they are now but corollaries of the main propositions.

It is not unnatural that admirers of the inductive sciences should place much emphasis upon teaching every subject by strict inductive methods or, on the other hand, that those who feel impelled to make short-cut deductive approaches the chief recourse for gaining time, should lay great stress upon verification of principles that are given and accepted as unquestionably true. Each tries in his way to satisfy the demands of his conscience for scientific procedure. But each of these extremes leads to undesirable results, for in the first case the student is often urged to prove by long inductive research a proposition that he already knows to be true, not indeed at first-hand, but by the dictum of those whom he trusts, while in the second case he is asked to verify that which he already knows in the same way to be correct. "What's the use," he exclaims, "of trying to prove either way propositions of which I am absolutely sure?" His work becomes perfunctory, observations are interpreted, not for what they actually reveal, but according to results that are

expected. Thus the scientific spirit is paralyzed in the house of its friends. Where then must the emphasis be laid, if not on induction or verification? The difficult and important thing in this stage of scientific teaching is, not the drawing of conclusions from supposed facts, or judging when a principle is verified, but the making of reliable observations with or without experiments, and an interpretation of them which is so far as possible unbiased by preconceptions. Strictly inductive processes are most effective when the student does not know, or at least is not certain, what is to be proved, for then he is, even if in miniature, the real investigator; while verification in the case of principles accepted on authority should be made, not so much to prove the principle as to use it to explain phenomena not hitherto comprehended. Verification so applied becomes a means of acquiring new knowledge. Correct and adequately interpreted observation is, therefore, the antecedent condition both of induction and of verification, and should be the school process most carefully developed.

It is when we come to the explanation of facts that scientific method makes its largest contribution to the methods of the school, for here thinking is the necessary condition of progress. The man who holds with the emotionalist that thinking is a disease cannot be an investigator, since phenomena cannot be explained, that is to say, causes cannot be discovered, classifications determined, or principles established, without active thought. It is quite possible, however, to seem to make progress in school with little or no live thinking, for the student can always memorize the facts and principles given by teacher or text. No real teacher need be told that such an attitude of mind is detrimental, if not fatal, to development. How effect by invention or device the ends we seek? How classify allied phenomena of the mineral, plant, and animal world? What is the function of this organ or part? Everywhere we meet the same state of things—to explain is to solve a problem. Outside the school every challenge to explanation comes in the form of some problem to be solved, whether it be to explain a natural

event, to decipher a hieroglyphic writing, or to restore the lost inscription on the Parthenon, which has left no key except the nail holes in the stones by means of which the letters are fastened on. If we ask why explanation in the outside world generates the problem, the answer is that it is the necessary intermediate stage between the unknown and the known. There is no other way of bridging this chasm when we are confronted by real situations, for authority is impotent here.

Whether school work shall fall into the problem form or not, depends upon whether explanation is to be made by the student's own thinking, or whether the teacher or the text shall do his thinking for him. That students shall truly think, not merely think that they think, must be held to be axiomatic by every thinking teacher.

Problems in the school, like those in the outside world, are both large and small. The major problems may take the strong persistent pull of days or weeks for their full and complete solution, while the minor ones, on the other hand, bring about kaleidoscopic interchange of question and answer, mental alertness arising from flashing insights into ground and consequence, instantaneous positing, accepting, or rejecting or modifying hypotheses—all of which are manifested in those forms of instruction that develop mind most rapidly and effectively. Here again the methods of science furnish us the most useful prototypes for the processes of instruction.

Again, just as it is vain effort for inventors of teaching devices to try to produce a full orchestral effect by playing on one string, so it is unwise to limit all thinking exercise to one form, say to that of *generalization,* even if this be used as a blanket term. Science again becomes our best guide, for her problems relate to the determination of facts as such by observation and experiment; then they relate to cause and effect in every realm of truth, to definition, to classification, to hypothesis, theory, rule, principle, law, formula, or what not, and she uses freely both induction and deduction, either simultaneously or in succession, and she employs with equal freedom all forms of analysis and synthesis. The methods of life are the macrocosm

of which those of the school are the microcosm, mirroring in their small way all the great processes outside.

A final difference between the investigator and the student pertains to the different methods by which they become efficient in the use of knowledge. The former attains efficiency in the use of his results partly through the concentration of his effort, and partly because they become a part of objective science to be used by all the world as occasion serves. A man who has spent years upon an invention knows how to utilize it when it is perfected; one who like Darwin devotes a lifetime to the establishment of principles such as those that control development, needs no specific exercise to train him to use the laws he has discovered. It is otherwise with the student, however, because in the nature of the case no great concentration is possible with him. Where the original investigator of a law, say of physics, spent weeks or years in its discovery, the student can devote but hours or at most days to its recapitulation. The amount of ground to be covered and the brevity of the time allowed compel the student to find efficiency in new ways if he is to become efficient at all. These new ways are necessary, even should they seem somewhat artificial to the worker in real science. As is well known, the student becomes efficient in the use of his knowledge to the extent to which he applies it in the explanation of phenomena kindred to those which give rise to it. In this way, as Dewey says, the content of knowledge which to the student is an individual acquisition, acquires the form of efficiency in the social world outside. Though the detail of the school is somewhat unlike that of the outside world, the spirit is still the same, for it would verify and perpetuate knowledge by making it a positive, a lasting force in society.

What then must we do to secure the substance of that whose phantom so many of us pursue? The answer is, read and digest the works of Mill, Bain, Jevons, Pearson, and Mach, and apply in the school the insight they give into the methods of the world of thought.